

ALTERNATIVE TRANSPORTATION TECHNOLOGIES OVER THE NEXT TEN YEARS – A TRANSPOWER PERSPECTIVE

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TRANSPower: VERTICALLY INTEGRATED BUSINESS MODEL

Total System Solutions

- ElecTruck™ electric drive system
- Grid-Saver™ stationary energy storage system
- Future: hybrid-electric and fuel cell drive systems



Business is driven by total system solutions for vehicle and stationary energy applications



Integrated Subsystems

- Energy storage subsystems
- Vehicle control subsystems
- Motive drive subsystems
- Electrically-driven accessory subsystems

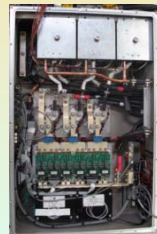


Complex subsystems are core to Company IP; can be integrated into systems or sold separately



Components

- Inverter-Charger Units
- Propulsion modules
- Automated manual transmissions
- Control modules
- Electrical and mechanical parts



Numerous proprietary components can be packaged into systems/subsystems or sold individually

TARGETED TRUCK MARKET SEGMENTS



Vehicle Type	Annual Estimates by 2023		
	Addressable Unit Sales	Drive System Price	Potential Drive System Revenue
Class 8 Port trucks	2,000	\$175,000	\$350,000
Class 8 Refuse trucks	10,000	\$200,000	\$2 billion
Class 7/8 Local delivery trucks	20,000	\$150,000	\$3 billion
Tactical military trucks	2,000	\$250,000	\$500 million
Construction and other vehicles	1,000	\$250,000	\$250 million
TOTAL	35,000*		\$6.1 billion

* 12.5% of U.S. market, based on 2013 factory sales of 279,783 trucks

- Class 8 trucks: 184,784
- Class 7 trucks: 47,524
- Class 6 trucks: 47,475

Source: WardsAuto

<http://trailer-bodybuilders.com/chassis/medium-and-heavy-truck-sales-28-december-6-2013>

TRANSPower: PRINCIPAL ELECTRIC VEHICLE PRODUCTS

- **Integrated Battery Energy Storage System** →

- Lithium-ion cells with advanced battery management
- combination of low cost and high performance
- Modular design for use in many applications



- **High-Power Inverter-Charger Unit (ICU)** →

- Combines functions of inverter and charger
- Controls main drive motor(s)
- Recharges batteries – no need for offboard charger



- **Main Propulsion Unit (MPU)** →

- Electric drive motor combined with transmission
- Unique “automated manual transmission” delivers high efficiency and performance across wide speed range



- **Electrically-Driven Accessory Subsystem** →

- Powers steering, braking, air conditioning systems
- Eliminates need for engine-driven accessories



- **Vehicle Control System** →

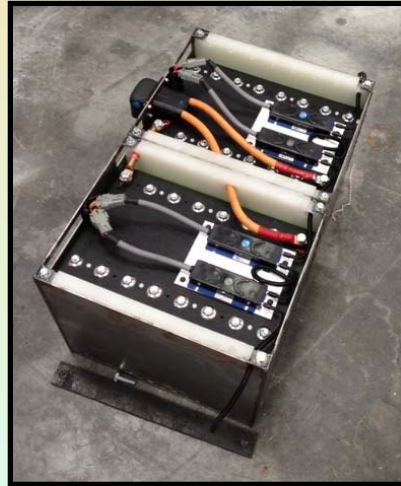
- Optimizes performance of above components
- Adaptable to a wide range of vehicles



KEY TECHNOLOGY CHALLENGES BY MAJOR VEHICLE SUBSYSTEM

Subsystem: Energy Storage

- Advanced cell balancing technology
- Low-cost battery enclosure manufacturing
- Battery pack testing and certification
- Battery pack swap technology



Subsystem: Power Conversion

- Low-cost inverter and charger manufacturing
- EMI characterization and mitigation
- Charger certification to UL, other standards



Subsystem: Motive Drive

- Compact, powerful, low cost motor technologies
 - Switched reluctance
 - Brushless DC
- Compact, lightweight, low cost gearbox
- Low-cost motor manufacturing



Subsystem : Vehicle Control

- Anticipatory controls
- Autonomous and semi-autonomous control
- Model-based design and CAN-based controls, easily modified for different mobile and stationary applications



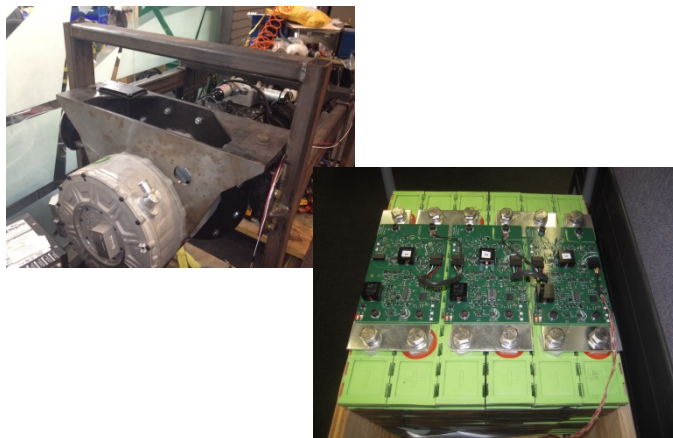
ARFVTP STRATEGIES TO ADDRESS COST CHALLENGES



- **Support larger scale demonstrations (10-50 vehicles)**
 - Achieve economies of scale
 - Attract stronger OEM (vehicle manufacturer) support
 - Accumulate miles needed to fully validate systems



- **Continue funding advanced manufacturing initiatives**
 - Component redesign for producibility and ease of integration
 - Tooling to enable lower cost processes (e.g., casting)
 - Fund pilot production runs of significant quantities of components



- **Focus smaller scale demonstrations (1-5 vehicles) on individual high cost-impact technologies**
 - Select a technology focus area for each demonstration (e.g., drive motors, battery balancing)
 - Use vehicles as rolling test-beds to achieve proof-of-concept of the selected technology

BEST OPPORTUNITIES FOR ELECTRIC DRIVE COST SAVINGS



- **Inverter-charger unit and related hardware**
 - Current cost: \$60,000
 - Long range target cost: \$25,000
 - Savings: **\$35,000** per vehicle
- **Powertrain (motors, transmission, and related)**
 - Current cost: \$25,000
 - Long range target cost: \$10,000
 - Savings: **\$15,000** per vehicle
- **Battery structures and integration hardware**
 - Current cost: \$10,000
 - Long range target cost: \$1,000
 - Savings: **\$9,000** per vehicle
- **Battery management and balancing**
 - Current cost: \$8,000
 - Long range target cost: \$2,000
 - Savings: **\$6,000** per vehicle
- **Subsystem and vehicle integration methods**
 - Current cost: \$200,000
 - Long range target cost: \$65,000
 - Savings: **\$135,000** per vehicle



TOTAL POTENTIAL SAVINGS: \$200,000 PER VEHICLE